High-p_T Particle Production in PHENIX

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Abstract. It has been established that "hard probes", observables involving high-momentum transfer, provide useful tools for studying the hot, dense medium created in nucleus-nucleus collisions at RHIC. The nuclear modification factor, azimuthal correlations, direct photon production, as well as the dependence of the nuclear modificaton factor on centrality and angle with respect to the reaction plane are critical for understanding the early dynamics of such heavy-ion collisions. We will review recent results from PHENIX for particle production at high-p_T and discuss their implications.

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INTRODUCTION

PHENIX is an ongoing experiment at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory, dedicated to searching for evidence of a phase transition from normal nuclear matter to the Quark Gluon Plasma (QGP). The QGP is a phase of matter consisting deconfined quarks and gluons expected to be formed at high energy densities (above ≈ 1 GeV/fm^3).

High-p_T observables are a critical probe for understanding the evolution of the collision region. Specifically PHENIX excels in measuring high-p_T neutral mesons and photons. An important tool for characterizing the production of high-p_T photons and hadrons, and for studying medium-induced effects on such particle production, is the nuclear modification factor R_{AA}:

$$R_{AA}(p_T) = \frac{d^2N_{AA}/dydp_T}{\langle T_{AA}\rangle d^2N_{pp}/dydp_T} \tag{1}$$

where $\langle T_{AA}\rangle$ is the nuclear overlap function for the given centrality of the collision. The denominator represents the expected yield supposing the A+A collision is a superposition of nucleon-nucleon collisions. Therefore, for the high-p_T region (> 2 GeV/c) where the physics is dominated by hard-scattering of partons, any deviation from unity is expected to arise from medium effects.

PHENIX HIGH-p_T MEASUREMENT

The PHENIX detector is described in [1]. High-p_T neutral mesons and direct photons are measured using the Electromagnetic Calorimeter (EMCal) [2]. The EMCal consists of 8 sectors covering π radians in azimuth and $|\eta| < 0.35$ in pseudorapidity. For measurements made with respect to the reaction plane, the reaction plane orientation is determined on an event-by-event basis using the Beam-Beam-Counters (BBCs) [3, 4].

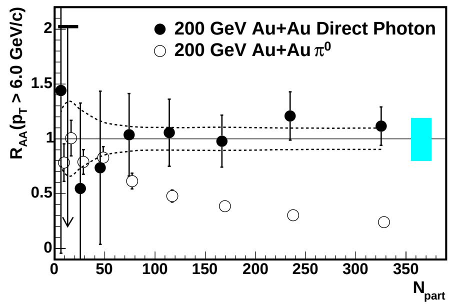

FIGURE 1. R_{AA} (integrated above $p_T > 6$ GeV/c) as a function of centrality (N_{part}) for direct photons and π^0s in 200 GeV Au+Au collisions. The band shows the uncertainty in the pQCD normalization.

An important baseline measurement that established the validity of perturbative QCD as it applies to heavy-ion collisions, as well as provide indisputable evidence of hard-scattering occuring at RHIC collisions, is the R_{AA} of direct photons [5]. Figure 1 shows the direct photon R_{AA} as a function of the number of participants, N_{part}. Also shown is the R_{AA} for π^0s. The comparison is striking: the photons have an R_{AA} consistent with unity, while the π^0s exhibit suppression. Since the photons will not be subject to final state effects, this represents clear evidence that the suppression is due to hadronic medium effects. We now know that this has to be due to final state effects, as the suppression is absent in d+Au collisions [6].

Preliminary inclusive π^0 R_{AA} is shown in Figure 2, for two sample centrality classes of $\sqrt{s_{NN}} = 200$ GeV Au+Au collisions from RHIC Run 4. We see that in central collisions the previously observed suppression exists up to $p_T \approx 20$ GeV/c. The GLV model [7] describes the suppression well, and implies the data are consistent with $dN_g/dy \approx 1100$ and an energy density ≈ 15 GeV/fm^3.

In order to help constrain energy loss models that attempt to describe hadronic suppression, an analysis of R_{AA} as a function of angle of emission with respect to the reaction has been proposed [4]. Preliminary results of measurements of this observable are shown in Figure 3. We note that although $R_{AA}(\Delta\phi)$ does not contain any new information that is not already available in a separate measurement of R_{AA} and the elliptic flow parameter v_2, this is the first type of measurement that combines those two observables in a single measurement. The angular variation of R_{AA} for a given p_T range can be compared to the corresponding data points in Figure 2.

There are other high-p_T observables, the description of which is beyond the scope of this paper. Azimuthal anisotropy [8] and jet structure via two-particle correlations [9] are two examples.

SUMMARY

PHENIX measures a broad range of high-p_T observables targeted at understanding the transition from normal nuclear matter to the QGP. Presented here are highlights of measurements of R_{AA} for photons and π^0s observed in $\sqrt{s_{NN}} = 200$ GeV Au+Au

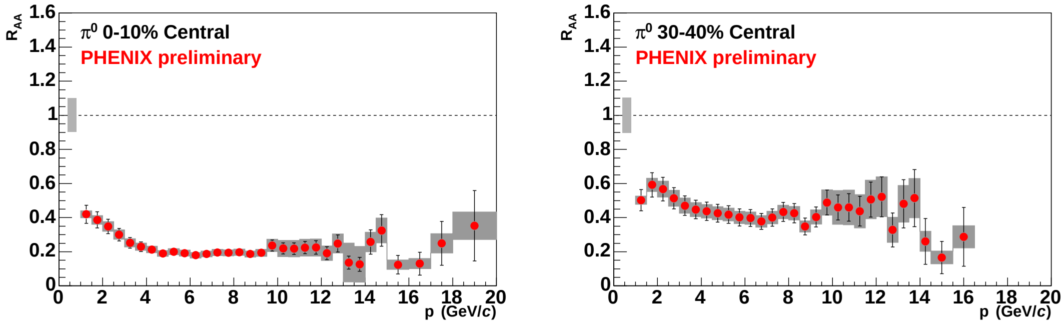

FIGURE 2. Inclusive π^0 $R_{AA}(p_T)$ 200 GeV/c Au+Au collisions. The boxes are the p_T-dependent systematic errors, and the systematic error on the normalization is shown as the box around unity.

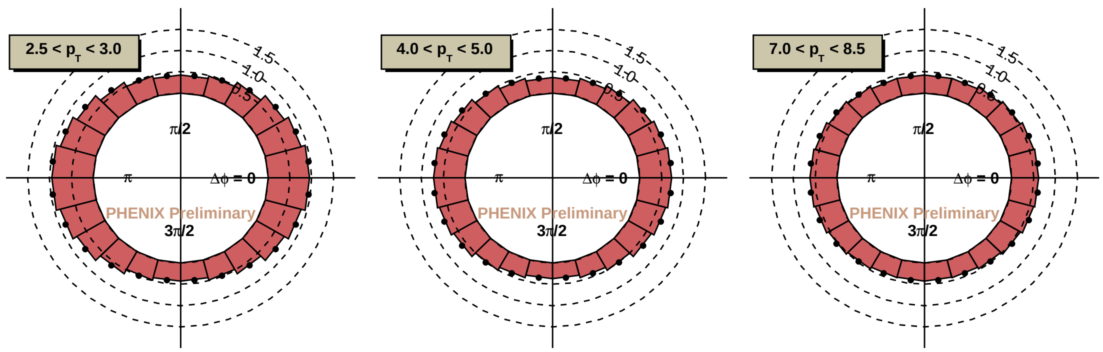

FIGURE 3. Polar plots of π^0 R_{AA} (p_T,$\Delta\phi$) for 30-40% central 200 GeV Au+Au collisions, for three selected p_T ranges. The measured $0-\pi/2$ rad data are folded to display the full 2π range. Errors shown are statistical only.

collisions. These data show clear evidence for strong hadronic suppression in central collisions, which is attributed to final state effects. Furthermore, the central data are consistent with $dN_g/dy \approx 1100$ and large energy density. Also presented is the PHENIX measurement of R_{AA} with respect to the reaction plane, which will be an effective to tool to allow more detailed study of the models used to describe energy loss at high-p_T.

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